SOLAR PHYSICS[1]

II.

We now have to consider what is the best method by which we can obtain, not a reversed image of the infra-red region, but a direct image of that portion of the spectrum; the problem had to be attacked in an experimental manner. It was really a matter of physics, and nothing more; the chemical question was *hors de combat*. Every silver salt which I have already shown you, you saw absorbed in the blue end of the spectrum, and not in the red; and therefore from what I had previously told you, you were prepared to hear that those salts would not be photographically effective for the red end of the spectrum, although they would be eminently so for the blue end. The question then we asked ourselves was this: Is it possible to obtain a silver salt which shall absorb in the red end of the spectrum? Is it possible, for instance, to obtain a salt of silver which will exhibit two molecular states—one absorbing in the blue, and the other in the red? If we turn to other bodies I think I can show you that there are bodies which exist in two or more molecular states. The very example of obtaining a reversed negative in the red of the spectrum by Draper's plan is an example of it. I have here another very good example of the oxidation process. This is chloride of silver paper which has been darkened by white light, and you will see that it has a tint which naturally would absorb to a certain extent the red rays. You will further see by the oxidising action we are able to produce a coloured oxide of silver. In other words, we have a coloured spectrum produced by the action of light itself, owing to the oxidising process. Alongside of this is the spectrum, taken on similar paper, without any preliminary exposure to light. You see where we get a darkened salt we have an impression of the spectrum in various colours, beginning with the blue, green, and then the red of the spectrum. Where the red end of the spectrum is you have a red oxide of silver formed.

Now let me show you that there are two different molecular states of elementary matter with which we are well acquainted. First of all I will throw a spectrum on the screen, and try to show you that there are two forms of iodine which absorb in different parts of the spectrum, telling us that they are molecularly different, when in solution at all events. The spectrum is on the screen, and I place a solution of iodine which has been dissolved in water in front of the slit, and you see that it cuts off the whole of the blue end of the spectrum, leaving only a red band. If you look at the white screen on the wall on the right you willsee an image of the slit reflected from the back of the prism, which gives the real colour of the iodine in solution. In this form, then, we have one molecular state of iodine. We will take another molecular state obtained by dissolving it in bisulphide of carbon. You see that we have a totally different absorption. The yellow is cut out, and the blue and also the red are left behind. Here, then, is one proof that we can have two molecular states of an element. But there is another interesting example in gold. If you will allow me to read from a book written by my colleague, Mr. Lockyer, he refers to the two molecular states of gold; and if possible, I should like to show you those different molecular states as far as we can on the screen. After talking about different kinds of spectra he goes on to say: "Gold is sometimes yellow, as you know, but gold is sometimes blue and sometimes red. It must be perfectly clear to all that if particles vibrate, the colours of substances must have something to do with the vibrations. If the colours have anything to do with the particles it must be with their vibrations. Now as the spectrum in the main consists of red, yellow, and blue, the red and the blue rays are owing to something in a substance which only transmits or reflects the yellow light: if we put gold leaf in front of the limelight, we can see whether the yellow light does or does not suffer any change. The yellow disappears; we have a green colour; the red and blue are absent. The gold leaf is of excessive thickness. What would happen could I make it thicker? Its colour would become more violet. This I have proved by using aqua regia. But we can obtain a solution of fine gold which lets the red light through. Its particles are doing something with the blue vibrations. We can obtain another solution which only transmits the blue. Now what is the difference—the 'particular' difference—between the gold in these solutions and that which is yellow by reflected light, and green or violet by transmitted light? It is a question worthy of much study."[1]

I will now throw on the screen an image of a thin film of gold kindly lent me by Mr. Lockyer, and you will see the colour of gold as it really is. It is not yellow, as we ordinarily know it, but is green when of that particular thickness, and it cuts off the red of the spectrum. I have here a solution of gold, which however does let red light through. It is purely metallic gold precipitated in water, and you will see what a beautiful red colour this has. This ruby colour of gold was first obtained by Dr. Hugo Müller, and experimented upon by Faraday. You can obtain also another solution of gold which is a greenish blue. It is rather a ticklish thing to show on the screen, but I daresay we shall be able to show it to you. Thus, then, we have gold in three states: the red molecular state, the blue molecular state, and the green molecular state; or perhaps the green may be referred to the difference between those two, or a combination of those two. Evidently, then, it is possible to obtain matter in two or three molecular states at the very least.

Now to apply this to our silver salts. Experience seems to show that the green molecules will be much more likely to absorb in the red than the blue molecules. I will just try to explain this by passing one or two green bodies before the slit of the spectrum apparatus (Fig. 6). In this green glass, for instance, you see that the red is cut off markedly from the green. Now if we take a solution of a salt of copper—chloride of copper—you will remark that the same phenomenon presents itself; we have the red cut off as well as the blue. You may ask the question whether a blue colour may not be equally as effective in absorbing the red as the green. I think I can answer this question experimentally. Here we have a piece of ordinary blue glass; you will see that although the red of the spectrum is dimmed to a certain extent, still a streak of red appears, and the principal absorption takes place in the yellow. One would naturally infer that as the red was not entirely cut off, those rays which lie below the red would also not be cut off. That, practically speaking, is found to be the case. We will take an ordinary blue dye, and you will find that we get the same phenomenon occurring. You will notice that the image of the slit on the side screen is a most beautiful Oxford blue, and you notice in the spectrum that it is gradually cutting out the yellow. Such experiments might be multiplied, but from what you have seen it is evident that a green is more likely to be effective as a red absorber than is blue, and this would apply also to the silver salt as regards the molecular state which we wish to produce.

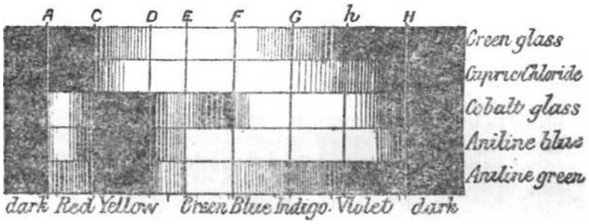

FIG. 6.—Absorption spectra of different coloured matters.

You may ask me—why cannot we use a green dye according to Vogel's method, which I mentioned last time? I can show you on the screen what would have happened with a green dye. There are greens and greens: some greens absorb in the red, others do not. In the ordinary green dye, which is a very complex body, part of the blue and part of the yellow is cut off, but not the red or the green, and consequently, as the red appeared it was perfectly useless to attempt to dye a film in order to produce a photograph of that end of the spectrum. What remained then to do? It simply remained to take some *simple* silver salt itself, and then to convert it into the molecular state, which would absorb the red. After four years of labour we succeeded in effecting this. In this test-tube we have some precipitated bromide of silver, which, as you saw on the screen last time, is of a yellow tint, or rather of an orange tint. Now bromide of silver is to a very small extent soluble in nitrate of silver, more particularly when acidified with nitric acid; and if such bromide of silver as we have here be boiled in a solution of nitrate of silver together with nitric acid, particular particles of bromide of silver are dissolved by the nitrate of silver, and then are re-deposited, built up, as it were, into bigger and bigger molecules, until finally we find we have a bromide of silver which literally is green when placed before the lantern. These two plates are respectively coated with the two kinds of bromide; first we have the ordinary bromide; and second, the bromide modified in molecular structure in the way I have described. The light from the lantern traverses the two films placed side by side, and you will see that they are eminently different in every way: the one being of an orange tint, absorbs the blue rays, the other being of a greenish-blue tint, absorbs the red. Now to show you that those two states are identical as far as the chemical composition of the molecules is concerned, I will take the green bromide of silver film which I had just now, and rub it with my finger; you will find that the blue bromide is once more reconverted into the red bromide. It has been scratched a little in the rubbing, and you will see, where the scratching has taken place, that it is of a fine orange tint. Here then we have a solution of the problem, the production of a bromide which will absorb in the red as well as one which can absorb in the blue, which is the ordinary state.

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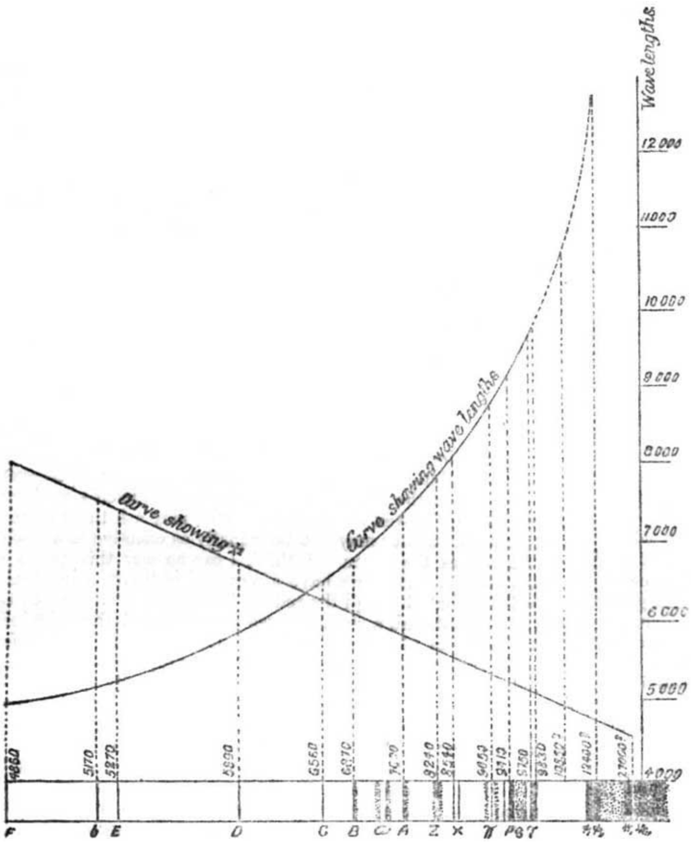
[1] Lecture delivered on May 25, 1881, at the Lecture Theatre, South Kensington Museum, by Capt. Abney, R.E., F.R.S. Continued from p. 166.

[1] P. 129, "Studies in Spectrum Analysis," by J. Norman Lockyer, F.R.S.; "International Scientific Series." (Kegan Paul and Co.)



Prismatic Solar Spectrum.
Measured from a Photograph.

FIG. 7.—Diagram of the least refrangible portion of the solar spectrum.

Now no sooner was this bromide obtained than, of course, there was great interest displayed to test its effect as regards its being a photographic salt. To do this we naturally appealed to the spectrum. But here I have something which will be perhaps more efficacious in showing you what that salt can do than anything else. This is a photograph of the poles of an electric light taken through this sheet of black ebonite. It is perfectly opaque to all visible radiation, but through it those rays which are below the red can penetrate to a certain extent. You see then we are able to photograph with the dark rays, absolutely without using the visible rays at all. Another example of this might probably be interesting for you to see, and that is this: it is an experiment I carried out to-day, so that it is fresh in my memory. Here I have a card pierced with a few holes That card was taken and laid very nearly, but not quite, in contact with this blue bromide film, and over it was placed a blackened kettle of boiling water. If those dark rays had any effect on the blue bromide, the radiations from the kettle of boiling water ought to alter the salt. Let us see whether it did so. The photograph is rough, but still I daresay it is specific enough to show you the result. You will see that the images of these holes are exactly reproduced, and the source of illumination, if it may be so called, was the kettle of boiling water, the radiations of which sufficed to cause an alteration in the silver salt. I have been able once—I have not tried to repeat the experiment—to photograph a kettle of boiling water by its own radiation; that is to say, it became a source of light.

We will next appeal to the spectrum to see whether it is sensitive to all the radiations, and I hink you will find that it will answer our expectations to the highest degree. I have on the screen the first photograph of the prismatic spectrum which was taken with this salt. You will be able to note the position of the spectrum with regard to the blue, the green, the yellow, the red. Below the impression made by the latter we have the famous A line, and below this again we have an impression made by the infra-red rays. What we next attempted was of course to get better photographs than the one I have already shown you; and next to draw a map of the prismatic spectrum.

In the following diagram we have the results of the measurements of these photographs. You see to what an enormous extent the solar spectrum extends below the limit of the visible spectrum—the A line is seen with great difficulty in the spectroscope (Fig. 7). The last band in the photograph that I last showed you was the band marked τ, but below that there are other bands which I was subsequently able to obtain. It is very rarely that these bands can be photographed at all, not because the plate is not sensitive to those radiations, but simply because of the atmospheric absorption which cuts off these particular radiations and prevents them from reaching our earth. I may say that the theoretical limit of the prismatic spectrum is very nearly reached here—not quite, but nearly. Cauchet showed that if you set up along the length of the spectrum, as we have it here, the inverse square of the wave-length of any two lines, say the inverse square of the wave-length of the B line, and erected a perpendicular line of a length representing that particular number, and also of the wave-length of the F line say in the same way, and then joined of the points thus obtained, we should get a line on which the inverse squares of the wave-lengths of H G C D would lie, and also theoretically the wave-lengths of lines below the red. Thus if we took and joined two points, all the other inverse squares of the wave-lengths would lie along that line, very nearly. In that way a theoretical limit of the prismatic spectrum can be obtained; in other words, the prismatic spectrum must stop where the wave-length is infinity. You will see that in this diagram we very nearly reach the theoretical limit. Where there is no atmosphere to interfere with the radiation, it would be easy to reach it. Since the spectrum we photographed is the solar spectrum, between the slit and the source of radiation many miles of atmosphere with more or less aqueous vapour intervene, which prevent us obtaining the limit; but with the electric light the absolute limit can be reached on some occasions, though with some difficulty. It may be asked if we can assume that there is a practical as well as theoretical limit of the prismatic spectrum: and in answer to this I may say that the measurements made from other photographs, to which reference will be made, will demonstrate that one is fully justified in adopting the theory.

The disadvantage of using the prismatic spectrum for measurement is this: you will notice the waves are very much compressed as you get down towards the red. The ordinates to the curve (Fig. 7) represent the wave-length; andif you calculate the wave-lengths from the inverse squares given by the nearly straight line it forms a curve like the above.

Now owing to the compression of the ultra-red it was very difficult to decipher the full meaning of the impressions obtained in this ultra-red region, more particularly as regards the resolution of bands into lines. You saw there were very few lines apparently, but there were bands, and the question asked was, Could we resolve these bands into lines? You recollect that Draper had in his photograph three lines below the limit of the red end of the spectrum taken by the oxidising process. They did not go very far down as it turned out, but still, there they were, and I think I can show you that those lines and bands are resolvable into lines. To do that, of course, we have to use a diffraction grating. On that stand I have a diffraction grating similar to the one Mr. Lockyer showed you, which was used in all the researches on the spectrum. We have on the screen the spectra produced by the grating; you will see that even the first two which lie next to the bright central image of the slit are much feebler than the spectrum you ordinarily see on the screen, as Mr. Lockyer pointed out. If you turn the grating further round you will see that another spectrum comes on, and by turning it still further we get a third, and so on. They are all feeble, but the two last very feeble indeed, but still they are present; of course by turning the grating in the other direction we should get similar spectra on the other side of the central image of the slit. By holding the screen up rather closer to the source of light, we shall be able to see the spectra better. I want you to notice that the violet of the third spectrum overlaps the red of the second spectrum. In order to photograph the ultra-red of the first spectrum it was necessary to use some artifice to cut out those invisible rays which lie between the violet and the red, and belong to the ultra-violet of the second spectrum, and also the violet and the blue, and the green of the same spectrum. In order to do that we used various absorbing media, but the most practicable for the purpose we had in view was a solution of bichromate of potash in water of about 1-25th of an inch in thickness. You will see that bichromate of potash cuts off the violet and the blue, and leaves the red and yellow intact. This solution was used with the diffraction spectrum to photograph the ultra-red regions. I will throw a diagram on the screen to show the overlapping of the different spectra, to make it more clear. You see in the second order the H lines comes a little beyond A (Fig. 8), and in the third line they come as far as the D line. You will also notice that the bichromate of potash cuts off certain rays in the first order-spectrum, the same rays of the second-order spectrum, and those also in the third-order spectrum.

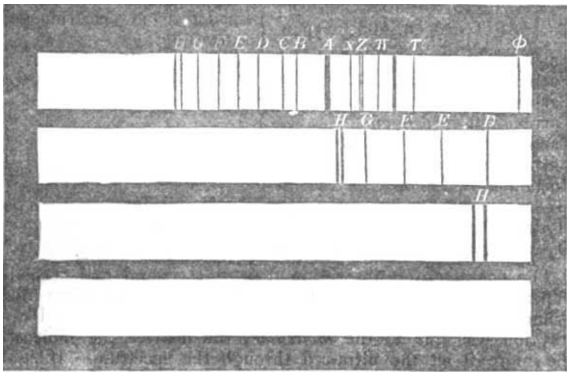


FIG. 8.—Overlap of the diffraction spectra of the 1st, 2nd, 3rd, and 4th orders.

I will now throw on the screen some photographs taken with this diffraction spectrum [shown and explained].

That is as far as we have been able to distinguish with the diffraction grating up to the present time, although we have hopes that with more labour we shall be able to get further down, not to the theoretical limit of the spectrum as shown by the diffraction grating, since that is infinitely far down, but at all events towards that way. In order to show how we can plot the wave-lengths it is only necessary to use the same plate of green bromide and to expose half the slit to the second-order spectrum for the blue end, and the other half to the first order of the red end of the spectrum, using, of course, proper absorbing media. In this photograph we adopted this artifice. The top half of the slit was exposed to the red end, and the bottom half to the blue, and so you see two spectra superposed one above the other (Fig. 9). Now we know that in the second order the wave-length of a line will be exactly half that of the wave-length of the next order which is above it. That is to say, suppose the wave-length of the H line to be 3900, the ultra-red ray which lies over it would be exactly 7800, and so on. By these means, by the coincidences of these lines one with the other, one is able to ascertain the exact wave-length of lines which lie in the ultra-red rays of the spectrum.

Then came the question, were we able to separate Draper's lines into bands, and were we able to separate these bands which we photographed into lines? Draper's three lines were separated into 250 distinct lines, and the bands on the screen into somewhere over 500.

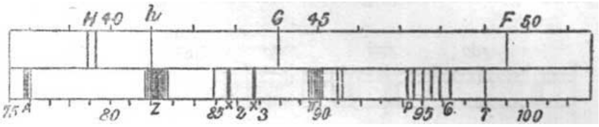


FIG. 9.—Method of determining the wave-lengths in the supra red region.

Having obtained means of photographing in the ultra-red region of the spectrum, what was the natural use to make of it? To introduce it into the photographic art? Not so, because there were considerations which prevented our doing so; but it seemed that there were other problems which might be settled very readily by recourse to another investigation. It seemed probable that colourless liquids ought to exercise absorption in the ultra-red regions. Nothing was known regarding them beyond the remarkable and well-known experiments made by Prof. Tyndall with a thermopile, with some source of radiation at a comparatively low temperature. He used a red-hot platinum spiral or a cube of hot water, and noted the radiation which was allowed to pass through different liquids and gases. But the knowledge obtained by this method was very much the same as if we were told that so much total visible light was cut off when examining the absorption spectra of coloured bodies. No definite knowledge was obtained as to the parts of the spectrum where the absorption of the liquids took place; in other words, Tyndall gave us a notification of the absorptions, and not their locality—a most important point.

Col. Festing joined with me in investigating this question, and we commenced, as might naturally be expected, by testing the absorption spectrum of water, and then we went on to a variety of hydrocarbons, such as the alcohol series, benzine, and so on. I need not recount to you all the various difficulties we found in our way; they were varied, but ultimately we were able to overcome them. Early in our work we had glimmerings of the truth that subsequently burst upon us in its full and truest light. The method we adopted was as follows:—You may imagine a source of light—the positive pole of the electric light forms a very brilliant source when cast by a lens upon the slit of the photo-spectroscope (Fig. 10). A tube of liquid, T, was placed between the lens and the slits: the rays were passed through prisms P, and eventually were received on the photographic plate F such as we have here. Passing sunlight through the top half of the slit, and then using the electric light to get the absorption spectrum of the liquid through the bottom half of the slit, we were able to compare either the solar spectrum with the absorption of the electric light after passing through any liquid; or by placing two different liquids before the top and bottom half of the slit we were able to compare their absorption spectra with each other.

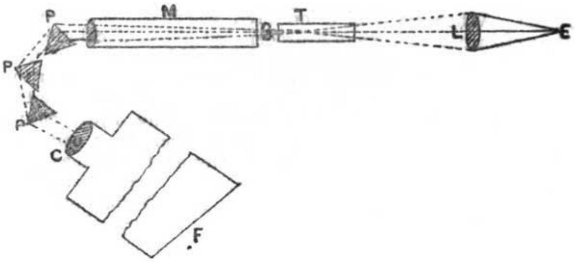


FIG. 10.—Apparatus used in photographing the absorption spectra of liquids.

Some of the first results we obtained were with hydrocarbon containing oxygen. Alcohol and ether are both hydrocarbons—they contain hydrogen, carbon, but also oxygen; and we noticed that in these oxygen compounds these bands of absorption were shaded bands, and not sharp and defined, as it were. We then went on to another series of compounds, or rather, part of the same group which contained no oxygen at all. Thus we worked with methyl iodide, ethyl iodide, and propyl iodide, and we found a very marked difference between the two spectra. We found that in the cases where there was no oxygen there were no shaded bands—that is to say, that if there were bands, they were sharp bands without shading at the sides (Fig. 11). What was the signification of this?

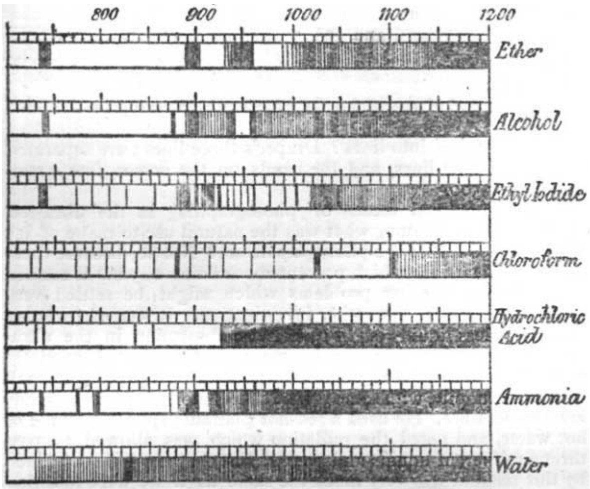


FIG. 11.—Absorption spectra of hydrocarbons, &c.

There must have been some meaning in it. Were the lines or the shaded bands due to carbon or to hydrogen? The lines could not be due to oxygen, because they were not present when oxygen was present. To what, then, could they be due? They must be due to carbon, hydrogen, or iodine; and which of these it became important to ascertain. In Fig. 11 we have a map of a selection of the different alcohols and the iodides, which were photographed. You will see that what I have said about alcohol is correct; that we have the shading off of the bands in the case of the alcohols. But when we come to the iodides we have a marked difference; we have lines springing up, as in ethyl iodide—distinct lines—which are also found in the other iodides. The question then was to trace these lines to their origin. If they were due to carbon we ought, of course, only to find them in carbon compounds; if they were due to hydrogen we ought only to find them where there was hydrogen. So we tried a series of substances, the absorptions of which I throw on the screen. When we tried chloroform, which contains only one atom of carbon and one of hydrogen, but three of chlorine, the whole spectrum became one of lines, nothing else but lines. These lines might be due to the carbon and hydrogen, or they might be due to the chlorine; so the next substance we tried was hydrochloric acid, which contains only hydrogen and chlorine. Here we have lines again which were coincident with some of the lines in the chloroform: those lines might still be due to hydrogen or chlorine. The next substance we tried was ammonia, which contains no chlorine, but three atoms of hydrogen and one of nitrogen. That gave lines again. We next tried carbon disulphide and carbon tetrachloride which contain neither hydrogen nor oxygen, with the result that we had neither bands nor lines. Evidently we had tracked the lines to their source; they were due to the oscillation of hydrogen in these particular compounds we had examined. When we took sulphuric acid we found the same result again; the bands were rather shaded, and to a certain extent it was the same in water also. The oxygen, as we shall see, formed these bands, but at the same time at the limit of the bands a distinct line was formed. Thus then we found in all the absorption spectra which contained lines, that those lines were due to hydrogen and nothing else.

I should next like to show you the further information we gained from these photographs. In the diagram we have the alcohol absorption spectrum, with a chloroform spectrum beneath it. The question to be answered is—Why should we have bands with sharp edges and fine lines in one case, and bands with sharp edges and bands shaded off in the other? In both cases the bands with sharp edges seem to be due to the base of the compound. Thus, in the case of the chloroform, the thick line or sharp-edged band seems to be due to the combination between carbon and hydrogen, and those other lines seem to be due to the vibration of hydrogen and nothing else.

What was the meaning however of the shaded bands as (say) in alcohol? When we came to the photographs it was found without exception that hydrocarbons containing oxygen, when not contained in the radical or base of the compound, always gave some shaded bands, and on measurement it was found that the shading always stopped at points where, in other spectra, we had marked the hydrogen lines. This coincidence was very remarkable, and could not be fortuitous; in fact, it seemed that there must be some connection between the position of these lines and the termination of the bands. The bands must be due to the oxygen in the compounds. What we eventually arrived at at last was this, that the oxygen blotted out the spectrum between two hydrogen lines; that is to say, if you look at it in one way, the oxygen oscillated between two hydrogen lines and cut out that particular portion of the spectrum. When we came to the benzine series, or in fact any other series, we found the same hold good: where we had hydrogen and no oxygen we had lines; where we had oxygen with the hydrogen we had bands. Where we had carbon, hydrogen, and oxygen, you see we had a shaded band and few lines; where we had carbon, hydrogen, and chlorine, or carbon, hydrogen, and bromine, or carbon, hydrogen, and iodine, or carbon and hydrogen alone, we had sharp-edged bands and many lines. Where we had carbon and chlorine, or carbon and nitrogen, or carbon and sulphur, we had no absorption whatever. That is to say, if you place bisulphide of carbon or cyanogen before the slit in one of these tubes we shall see no absorption take place except a general absorption. In other words, the absorption gradually increased and mounted up from the least refrangible end of the spectrum towards the blue end of the spectrum, and that was the only absorption which could be traced. The following table concisely shows the above:—

Carbon, Hydrogen, and Oxygen	Shaded band spectrum and few lines.
Carbon, Hydrogen, and Chlorine	Sharp-edged bands and many lines.
Carbon, Hydrogen, and Bromine	
Carbon, Hydrogen, and Iodine...	
Carbon and Hydrogen	
Carbon and Chlorine	No special absorption.
Carbon and Nitrogen	
Carbon and Sulphur	
Hydrogen and Oxygen	Bands and lines.
Hydrogen and Chlorine	Lines only.
Hydrogen and Nitrogen	Lines only.

The character of absorption then was general and special. Where we had special absorption bands they were due primarily to hydrogen *atoms* vibrating; whilst the general absorption was due to the *molecules;* the heavier the molecule the more it let the ultra-red through the spectrum. If bases of two series were present we found the absorption due to each base of these particular compounds present in the spectrum. Thus, by taking the absorption spectrum of, say, a compound of ethyl and benzine, we are able to say that the ethyl base was there and the benzine base was there also; the bases of these particular series being denoted by these thicker bands with sharp edges to which I have already referred.

Thus then spectrum analysis opened a way for the chemical analysis of these organic compounds, not of course in their entirety, but so as to get a qualitative idea of what they may contain.

The length of liquid generally employed was six inches, and the natural question to ask is, What is the difference caused by increasing or diminishing the thickness of the liquid between the slit and the source of light? If you increase the thickness of the liquid between the slit and the source of light, it is this: Where you have oxygen bands you have them shaded off; increasing in intensity, but spreading further—they do not spread further in a nondescript way, but in a very marked manner they spread out to the next hydrogen line, and so on. Therefore, supposing with a very small thickness we have oxygen bands extending between two hydrogen lines, in the next six inches of liquid the absorption will cover three hydrogen lines, and so on. Where you have lines, the lines never alter; where you have those base bands, or radicle bands, as they are called, they never alter; they are always in the same position, and never spread out or diminish either to the right or left. When you diminish the thickness of the fluid those bands are always present, and they are the last things to disappear in the absorption spectra.

Another remarkable thing with regard to these compounds is, as a rule there are two bands which are characteristic of their base. There is a band which is nearly always situated near the limit of the red, and another between wave-lengths 8000 to 11,000. That is to say, there is always a band to be seen somewhere about "*a*," and another somewhere about *ρ*. Those are characteristic of any particular compound we may have present.

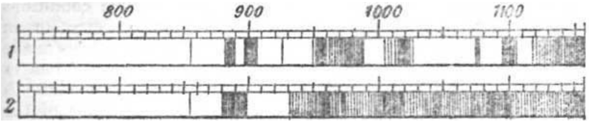


FIG. 12.—Absorption spectra of aldehyde and par-aldehyde.

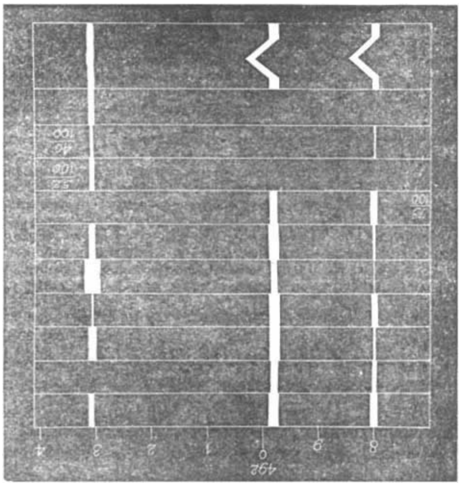


FIG. 13.—Diagram of three iron lines as observed by Lockyer.

You may say that I have been giving you a lecture on chemistry but in reality it is one which I hope may lead to results in solar physics. And I now venture to tell you how (Fig. 12). Here is a pair of bodies which we examined, to which I wish to draw your particular attention, namely, the spectra of aldehyde and par-aldehyde. Now aldehyde and par-aldehyde are the same bodies exactly in composition, only chemists tell us that par-aldehyde has three molecules of aldehyde in its one molecule—the only difference then between them is that there are three molecules of aldehyde combined to form par-aldehyde; aldehyde of course being one molecule by itself. Not only do chemists tell us that this is the case, but they know it, because if they heat par-aldehyde they get aldehyde formed again, and can reconvert this into par-aldehyde. Now I want you to notice the difference in the spectra between these two bodies. We have two bodies of the same chemical composition and of different molecular grouping, and you will see there is a total distinction in the two absorption spectra they yield. The only thing in common is the radical band. There may be one or two other coincidences, but all the rest of the spectra are perfectly distinct. Now if you refer back to Mr. Lockyer's lectures I think this alone will throw some light on what he has already said to you. He has told you, for instance, that the spectrum of iron in the flames and the spectrum of iron in the spots are dissimilar; and he has kindly furnished me with a photograph which shows one little part of the spectrum in which this is exemplified in a remarkable degree. In it we have three iron lines close to one another (Fig. 13). In the sun-spots two of those only appear, and in the flames the third alone appears If you look at this by the light of that photograph of aldehyde and par-aldehyde which I had on the screen, I think it is a reasonable deduction to make that the iron in the flame and that in the sun-spots have different molecular groupings. I say that this spectral analysis to which we have subjected aldehyde and par-aldehyde, and many other similarly constituted bodies, lends confirmation to that view. Of course, in the case of organic compounds, we can appeal to the chemist to analyse them for us, and he tells us that they are different molecular groupings. It is scarcely fair in one case to admit that the two spectra are given by two molecular groupings of the same substance, and in the other to deny it.

Again, we found that many lines were common to each hydrocarbon: thus we found a line at 867 of the scale, common to benzine and to alcohol; and to take one particular case, we found a special line common to water, hydrochloric acid, and chloroform. Has this any bearing on what you have heard? Mr. Lockyer has told you that some short lines are to be found in two, three, four, or even six different metals, not taking the long lines into account, as they might be considered to be due to impurities in the different spectra. Let us apply this to our case. A certain substance, A, has certain lines coincident with B; B also has certain lines coincident with C; and C also has other lines coincident with A. Now we will suppose these hydrocarbons were looked upon as elements, but that eventually the chemists split up what they considered elements, and found that the only substance which was common to the three was hydrogen. I leave you to draw the parallel between Mr. Lockyer's experiments and those which I have endeavoured, in a very rough and unsatisfactory manner, to bring before you. I think, if the chemist will admit that in the case of the hydrocarbons it is hydrogen which produces the lines common to all, there is no reason on earth, supposing the metals are not elements, why you should conceive that they should not have a common constituent in the same way that the organic compounds have a common constituent in the shape of hydrogen. I leave that for your consideration.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

OXFORD.—Among the professorial notices of next term's lectures already published are those of the Professors of Astronomy, Geology, Botany, and Medicine.

Prof. Pritchard will give three courses at the University Observatory. He will lecture on the Lunar and planetary Theories, and will form two classes for practical instruction in the evenings. Prof. Prestwich will lecture on Stratigraphical Geology in the University Museum. Prof. Lawson will lecture on the Elements of Systematic Botany at the Botanic Garden.

The Professor of Medicine, Dr. Acland, gives notice that the next examination for a Radcliffe Travelling Fellowship will commence in the second week of February. Candidates are requested to communicate with the Professor.

The professors and lecturers engaged in teaching Physics have settled a combined system of lectures for next term as below:—

Hydromechanics, by Prof. Price; (1) Distribution of Terrestrial Magnetism, (2) Electricity developed by Contact of different Substances, by Prof. Clifton; Instruments and Methods employed in Optical Measurements, by Prof. Clifton; Practical Physics, by Prof. Clifton, Mr. Stocker, Mr. Heaton; The Generation and Measurement of Electric Currents, by Mr. Baynes; Electrostatics (treated Mathematically), by Mr. Hayes; Elementary Mechanics (treated Experimentally), by Mr. Stocker; Problems in Elementary Mechanics and Physics, by Mr. Heaton; Elementary Physics treated Experimentally (Heat and Light), by Mr. Dixon. The lectures on Optical Instruments are intended to serve as an introduction to the practical work in the laboratory. The last three courses of lectures are intended to meet the requirements of candidates for the Preliminary Honour Examination.

An examination for a Fellowship in biological subjects will be held at University College in February, 1882, beginning on Wednesday, February 22, at 9 a.m. Candidates are desired to call on Mr. C. J. Faulkner with the usual testimonials and certificates on Tuesday, February 21, between 5 and 6 p.m. But intending candidates are desired to send in their names to him before February 1, 1882, with a list of the subjects which they offer for examination, and at the same time to mention any branch of biology to which they have turned special